Attachment 1

TECHNICAL NOTE

Lockheed
Research & Development Division
Huntsville Research & Engineering Center
4800 Bradford Drive, Huntsville, AL 35807

Contract NAS8-34978 **Date** 11 Dec 1984 **Doc.** LMSC-HREC TN D951725

Title INVESTIGATION OF THE HPFTP FIRST STAGE IMPELLER CRACK

FOREWORD

This technical note was prepared by personnel in the Dynamics & Loads Group at the Huntsville Research & Engineering Center for NASA-Marshall Space Flight Center under Contract NAS8-34978. Mr. Norman L. Schlemmer, EP46, is the MSFC Contracting Officer's Representative for this contract.

INTRODUCTION

The occurrence of a crack in the HPFTP first stage impeller of pump 2608 R2 during test 750-245 prompted this analysis to examine possible causes of the failure. Preliminary analysis, using an existing NASTRAN model of the impeller, showed a deficiency in the model's ability to reliably calculate stress in the area of concern (outboard edge of the impeller shroud). A new NASTRAN model was constructed to better define the stress state in the area of crack initiations. Static stress analysis and normal modes analysis were performed on the new model. Results are presented on the following pages.

Model Description

Due to the complexity inherent in the impeller's geometry, a symmetry approach was indicated to permit sufficient modeling detail. The cyclic symmetry feature of NASTRAN is frequently used in such applications as modeling circular structures that have repeating segments around their circumference. It allows the user to model only one segment of the

(NASA-CR-171281) INVESTIGATION OF THE HPFTP FIRST STAGE IMPELLER CRACK (Lockheed Missiles and Space Co.) 13 p HC A02/MF A01 CSCL 20K
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structure while NASTRAN applies appropriate boundary conditions at the symmetric boundaries to simulate the complete structure.

A 60 degree segment of the impeller was modeled following the sweep of the region between full blades as shown in Fig. 1. Figure 2 shows a computer generated plot of the actual NASTRAN model, while Fig. 3 shows how each segment interfaces to form the complete impeller.

Analysis

Steady state loads shown in Fig. 4 were applied to the model resulting in the stress contours shown in Figs. 5 and 6. Stress values at the outboard edge of the shroud are tabulated in Fig. 7. Using the maximum stress from Fig. 7, an estimate of the maximum allowable alternating stress was calculated in Fig. 8. Figure 9 is a modified Goodman diagram. Frequency output from the normal modes analysis is shown in Figs. 10 and 11.

Conclusions

- Steady state stress is insufficient to cause failure.
- Large forcing function would be necessary to cause stress that approaches allowable alternating stress.
- Frequency content of impeller indicates the possibility of resonances as shown on Campbell diagram (Fig. 11).

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Attach: Figs. 1 through 11

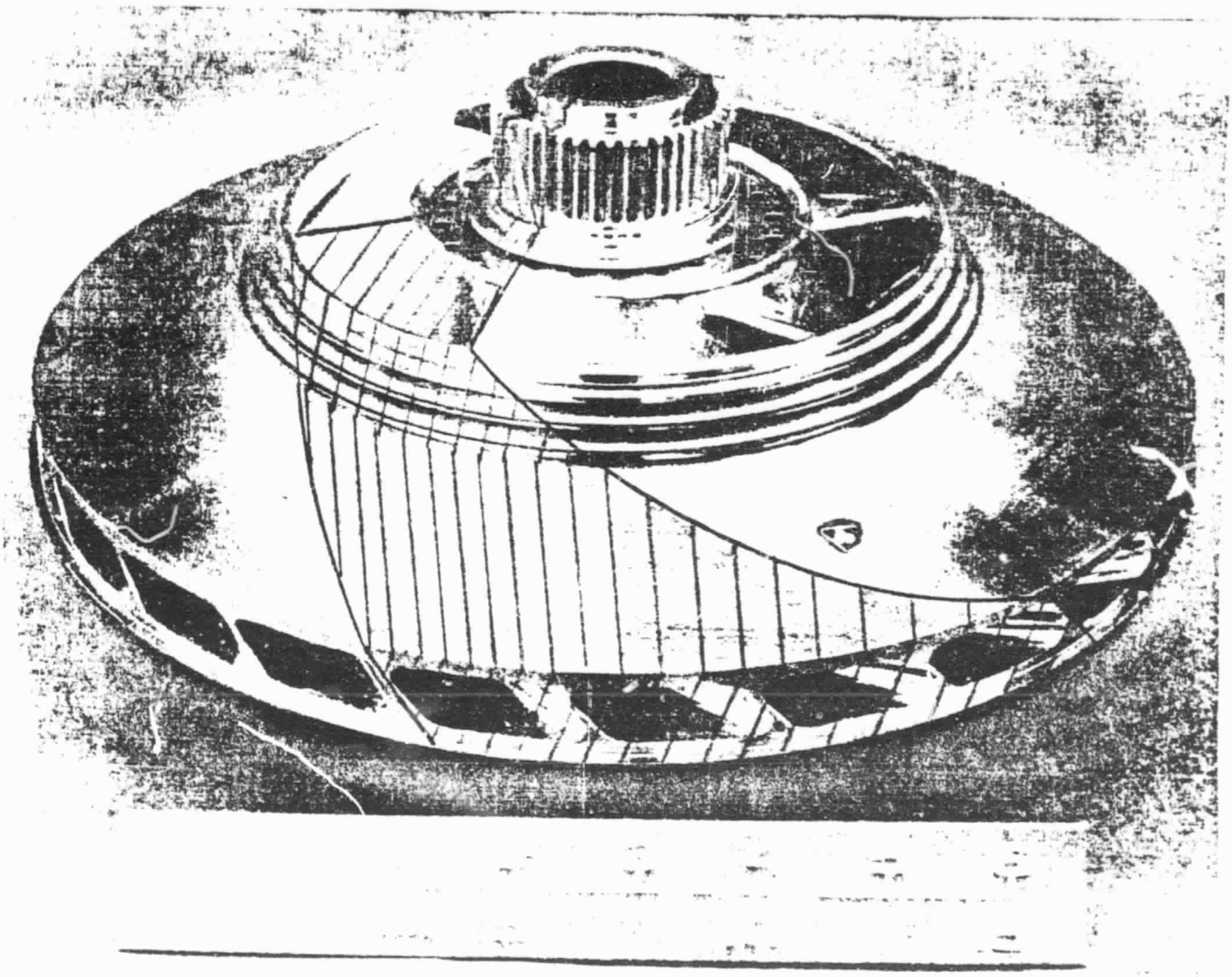

Fig. 1 60 deg Segment of Impeller Modeled with NASTRAN

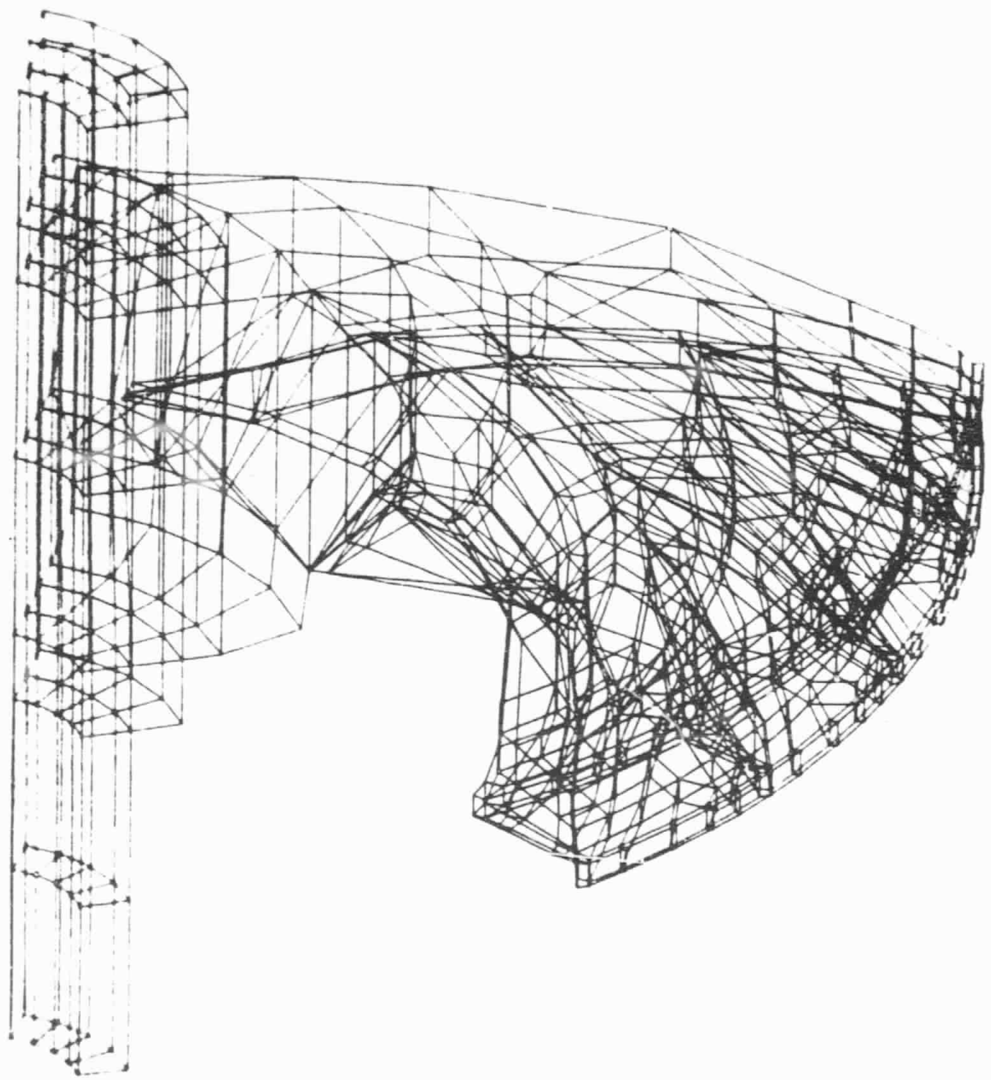

Fig. 2 NASTRAN Model of HPFTP Impeller (60 deg Segment)
764 Nodes, 418 Elements

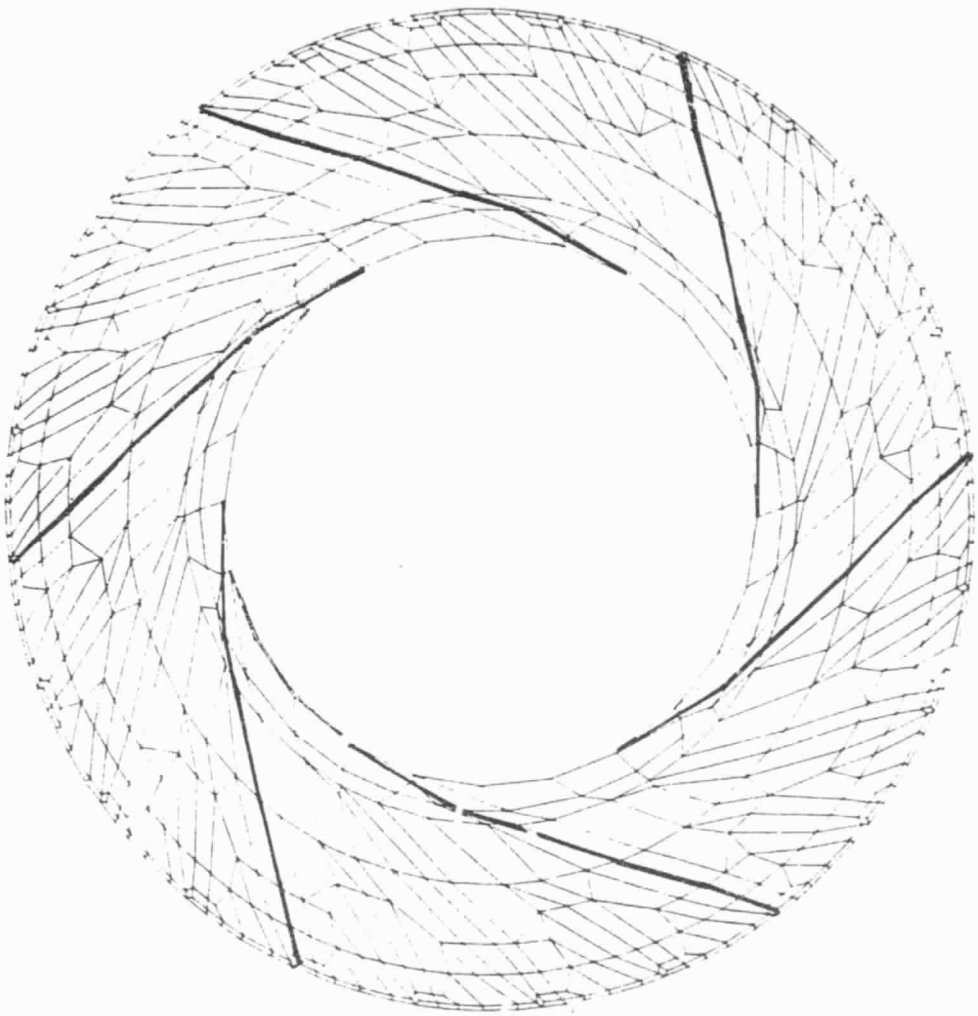

Fig. 3 Schematic of Segment Assembly (Shroud Only)

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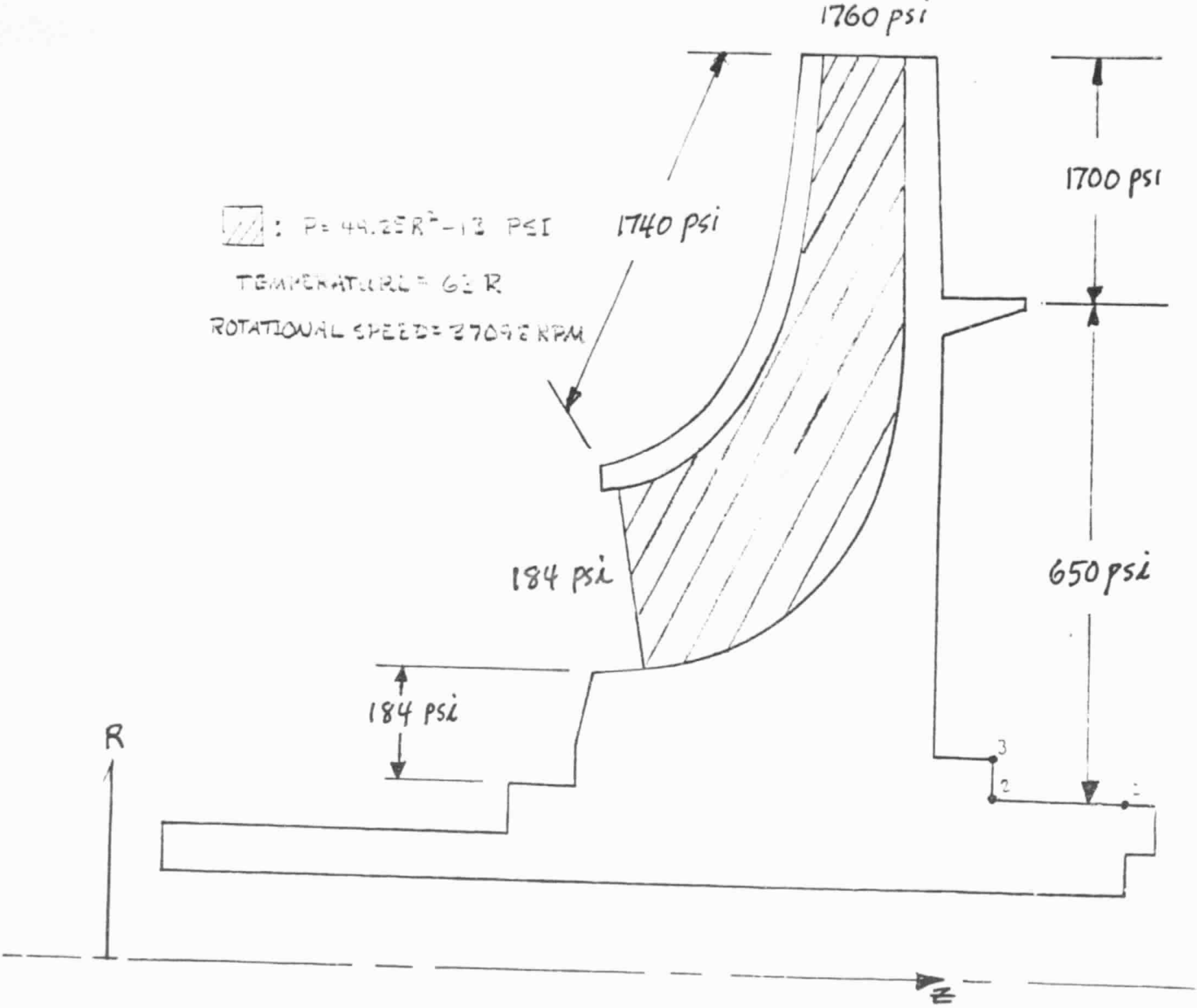

Fig. 4 Steady State Loads on HPFTP Impeller

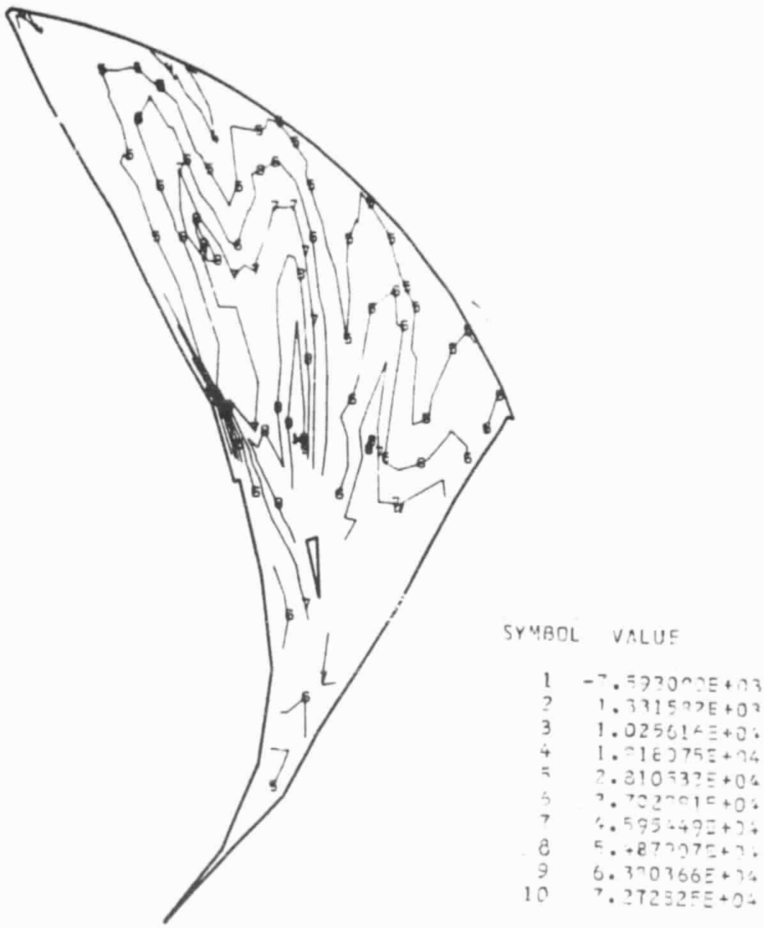

Fig. 5 Stress Distribution - Shroud External Surface
(Rotational Load Only)

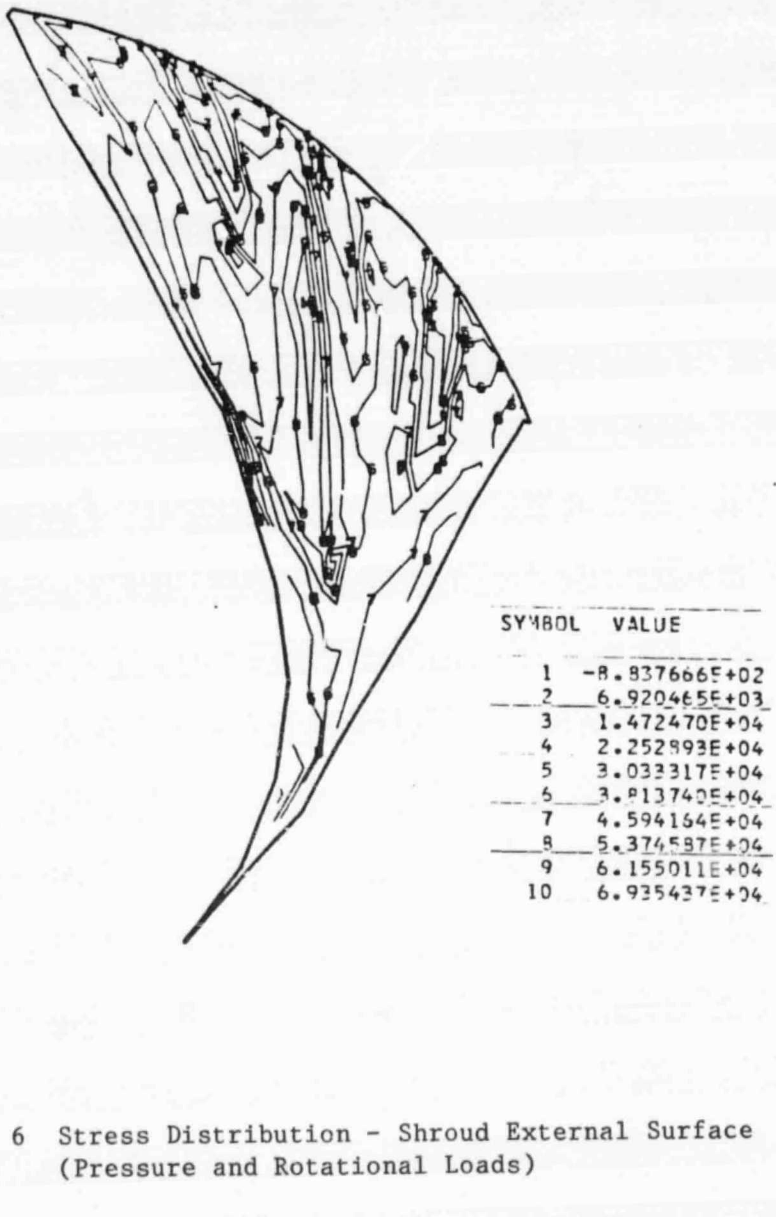

Fig. 6 Stress Distribution - Shroud External Surface (Pressure and Rotational Loads)

Circumferential Location	Rotational Load	Rotational & Pressure Load
0° - Full Blade		
2.5°	18.4	11.4
5.0°	23.4	21.4
7.5°	24.7	26.3
10.0°	23.4	33.2
12.5°	17.0	15.5
15° - Second Partial		
17.5°	17.6	3.9
20.0°	20.9	15.2
22.5°	21.6	20.8
25.0°	26.8	36.1
27.5°	24.2	25.4
30° - First Partial		
32.5°	23.7	15.8
35.0°	27.8	27.2
37.5°	25.7	29.5
40.0°	24.8	35.8
42.5°	23.1	21.9
45° - Second Partial		
47.5°	23.1	10.3
50.0°	24.5	20.2
52.5°	29.2	29.9
55.0°	33.4	44.4 *
57.5°	24.7	27.2
60° - Full Blade		

* = Max.

Fig. 7 Stress at Outboard Edge of Shroud

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(1) From static analysis, max stress is:

~ 45 KSI

(Note: At $-397°F$, $S_y = 170$ KSI, $S_u = 180$ KSI)

(2) Using the Modified Goodman Diagram (next page),

the allowable alternating stress for 10^7 cycles is:

46 KSI

(3) Reducing the stress by 3 standard deviations

to achieve an acceptable confidence level, we have:

$$46(1-.12)^3 = 31 \text{ KSI}$$

(Assuming a Coefficient of Variation of .12)

Allowable alternating stress = 31 KSI

Fig. 8 Calculation of Allowable Alternating Stress

ROCKWELL INTERNATIONAL
ROCKETDYNE DIVISION

MATERIALS PROPERTIES MANUAL

EXPECTED MINIMUM
AXIAL, MODIFIED GOODMAN DIAGRAM
MACHINED SURFACE 32 FINISH
ANNEALED 1400F

DATE- 9-1-77
REFERENCE- 5002 -04
2ND EDITION PAGE- 5.3.1.1.2.9

5002.33.12.50-04

TITANIUM-5AL-2.5 SN ELI	5002
HIGH CYCLE FATIGUE	.33
BAR AND FORGING	.12
ANNEALED	.50
PAGE NUMBER	-04

SPEC R30170-079

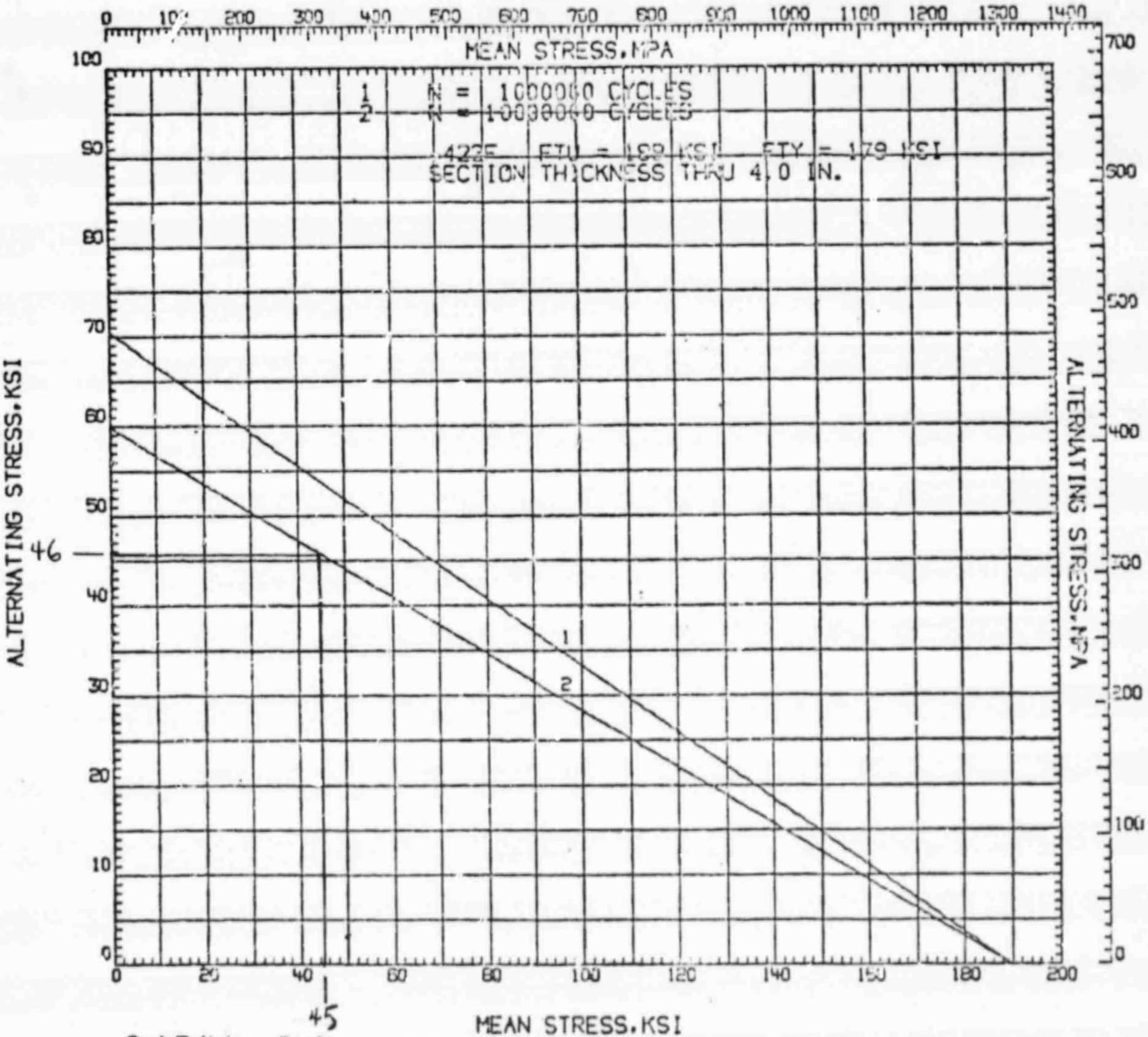

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Fig. 9 Modified Goodman Diagram TI-5AL-2.5SN

HARMONIC INDEX	MODE NUMBER	FREQUENCY (HERTZ)
K=0	1	1596
	2	2857
	3	7040
	4	11005
K=1	1-2	1529
	3-4	3801
	5-6	5797
	7-8	8359
	9-10	9597
	11	9875
	12	14126
K=2	1-2	3271
	3-4	7375
	5-6	8766
	7	12906

Fig. 10 HPFTP Impeller Frequency List

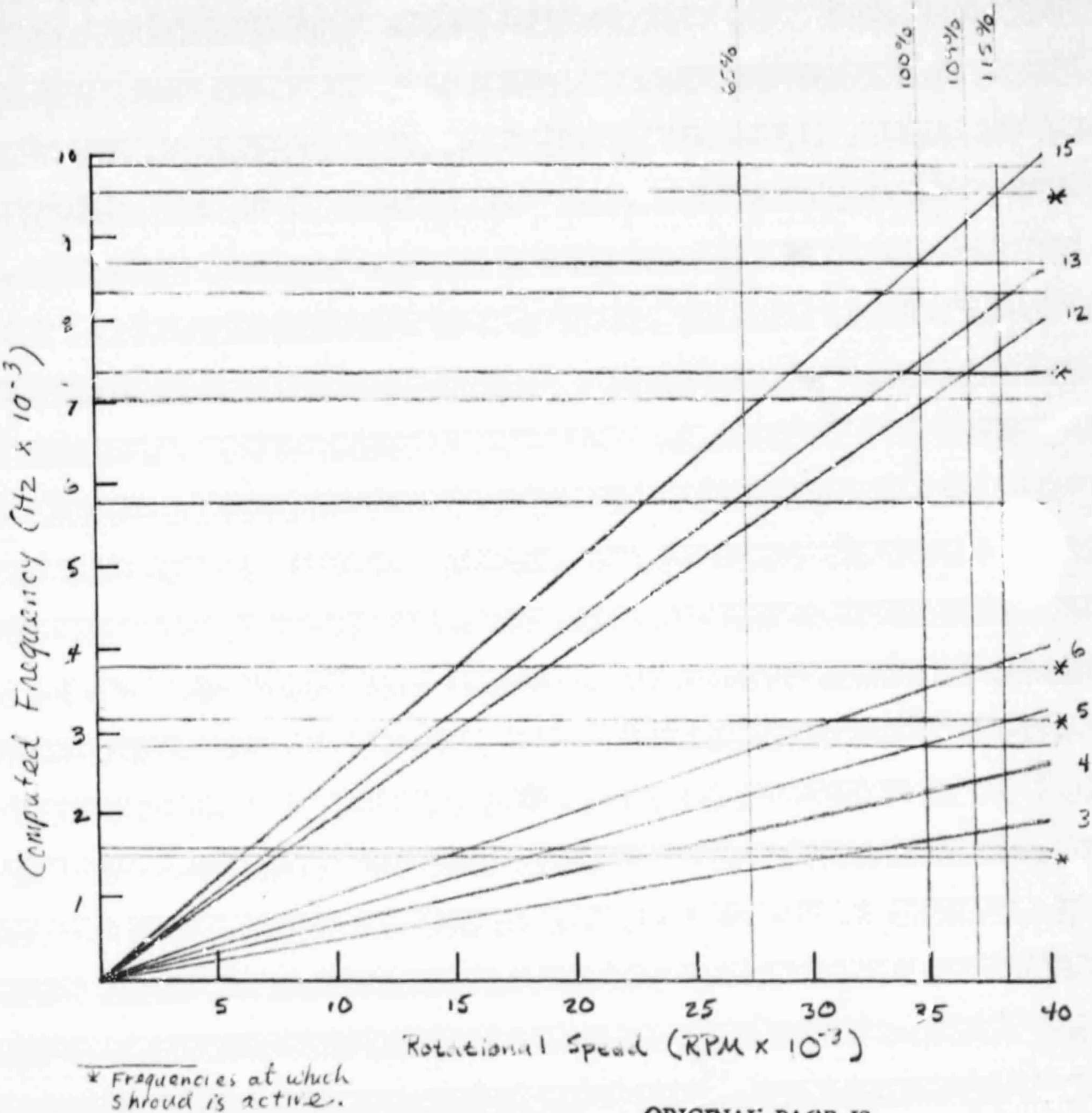

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Fig. 11 HPFTP Impeller Campbell Diagram